Salud, Ciencia y Tecnología. 2025; 5:1522
doi: 10.56294/saludcyt20251522

ORIGINAL

Investigating socioscientific decision-making of high school biology students based on gender and area coverage.

Investigar la toma de decisiones sociocientíficas de los estudiantes de biología de secundaria en función del género y la cobertura del área

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Citar como: Darmawan H, Mahanal S, Susilo H, Sueb S. Investigating socioscientific decision-making of high school biology students based on gender and area coverage. Salud, Ciencia y Tecnología. 2025; 5:1522. https://doi.org/10.56294/saludcyt20251522

Submitted: 16-08-2024 **Revised:** 01-11-2024 **Accepted:** 27-02-2025 **Published:** 28-02-2025

Editor: Prof. Dr. William Castillo-González

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ABSTRACT

Introduction: socioscientific decision-making involves the process of analysing complex problems, seeking relevant information, building arguments, applying critical thinking skills, and integrating diverse perspectives to arrive at a Solution. This study aims to explore the extent to which gender and geographical location affect students' socioscientific reasoning.
Method: it uses a quantitative research approach with a quantitative ex-post facto design. The research population consisted of all tenth-grade students in West Kalimantan Province. The sample for the study consisted of 912 students selected from public and private high schools. in Pontianak Municipality, Teluk Keramat District, and Paloh District, West Kalimantan Province, Indonesia. Participants were recruited using purposive random sampling. Students are then categorized based on gender and regional coverage. Gender criteria are visualized in men and women, while the criteria for regional coverage are urban (Municipal) and rural (District).
Results: the results of the study showed that male students significantly outperformed female students in socioscientific decision-making. This difference is evident in the quality of the arguments and explanations provided by male students in their essay responses, demonstrating a deeper understanding of the issue.
Conclusion: that there is a gap in socioscientific decision-making ability between students in urban and rural areas. The study revealed that urban students tend to have stronger socioscientific decision-making skills compared to rural students.

Keywords: Socioscientific; High School Student; Biology; Education.

RESUMEN

Introducción: la toma de decisiones sociocientíficas implica el proceso de analizar problemas complejos, buscar información relevante, construir argumentos, aplicar habilidades de pensamiento crítico e integrar diversas perspectivas para llegar a una solución. Este estudio tiene como objetivo explorar en qué medida el género y la ubicación geográfica afectan el razonamiento sociocientífico de los estudiantes.
Método: utiliza un enfoque de investigación cuantitativa con un diseño cuantitativo ex-post facto. La población investigadora estuvo constituida por todos los estudiantes de décimo grado de la provincia de Kalimantan Occidental. La muestra para el estudio estuvo constituida por 912 estudiantes seleccionados de escuelas secundarias públicas y privadas. en el municipio de Pontianak, distrito de Teluk Keramat, y en el distrito de Paloh, provincia de Kalimantan Occidental, Indonesia. Los participantes fueron reclutados mediante muestreo aleatorio intencional. Luego, los estudiantes se clasifican según el género y la cobertura regional. Los criterios de género se visualizan en hombres y mujeres, mientras que los criterios de cobertura

regional son urbanos (Municipales) y rurales (Distritos).
Resultados: los resultados del estudio mostraron que los estudiantes varones superaron significativamente a las estudiantes femeninas en la toma de decisiones sociocientíficas. Esta diferencia es evidente en la calidad de los argumentos y explicaciones proporcionados por los estudiantes varones en sus respuestas a los ensayos, lo que demuestra una comprensión más profunda del tema.
Conclusión: que existe una brecha en la capacidad de toma de decisiones sociocientíficas entre los estudiantes de las zonas urbanas y rurales. El estudio reveló que los estudiantes urbanos tienden a tener habilidades sociocientíficas más sólidas para la toma de decisiones en comparación con los estudiantes rurales.

Palabras clave: Sociocientífico; Estudiante de Bachillerato; Biología; Educación.

INTRODUCTION

The main function of education is to seek the truth and spark a spirit of lifelong learning in students. One method to allow students to expose more complex science interactions is to master certain skills in learning and prepare them to do.[1] It also encourages them to generate ideas and take part in decision-making on relevant socio-scientific topics. The concept of socioscientific decision-making is essential for 21st century skills with respect to this issue. According to[2] when faced with more complex difficulties in life, each individual is obliged to adapt and make the best choices.

Internal and external factors influence socioscientific decision-making.[3] This finding is reinforced by [4] which states that it is necessary to consider gender factors, level of experience, regional coverage, and depth of knowledge in decision-making that is integrated with socio-scientific issues. Internal factors that can affect decision-making include gender factors.[5] The issue of gender equality has been introduced in science education,[6] and has also been found in decision-making. These findings underscore that gender has an influence on socioscientific decision-making in science education.[7]

The decision-making process related to social and scientific problems is a process of making choices based on solutions to complex social and scientific problems that must be solved by students. This process begins with reflection on the problems faced, followed by information collection, argumentation, application of reasoning skills, and integration of various perspectives in the formulation of solution plans. Other opinions define socioscientific decision-making as the skills used to make decisions related to socioscientific issues involving scientific conflicts, evaluate the feasibility of decisions, consider risks based on evidence, and make alternative pros and cons of decisions based on ethical, environmental and social perspectives.[8]

Socio-scientific decision-making in developing countries is a complex and diverse topic that requires a nuanced understanding of the interaction between social, economic, and scientific factors. At the heart of the problem is the recognition that the decision-making process in the context in which it develops is not purely rational or objective, but rather strongly influenced by psychological, sociological, and political considerations. However, the successful implementation of such strategies depends on navigating the complex web of social norms, stakeholder needs, and power dynamics that shape the decision-making process. As such, experts have called for a deeper understanding of the underlying processes used to make these complex decisions, emphasizing the need to support decision-makers in evolving contexts.[9] Developing countries often face significant challenges in terms of urbanization, population growth, and resource constraints, which contribute to the complexity of socioscientific decision-making. In this context, the role of social science frameworks, such as those drawn from political science, economics, psychology, and sociology, becomes important in shaping environmental policies and promoting sustainable development.[10]

The challenges of socioscientific decision-making processes in developing countries are diverse and often linked to complex socioeconomic, political, and cultural factors. In the case of Indonesia, the education sector is a prime example of the need for a stronger and inclusive decision-making framework to address persistent inequality and quality gaps in the country.[11,12] Existing research on inclusive education in Indonesia paints a mixed picture – while there have been some positive steps towards greater inclusivity, a significant gap remains between the needs of children with special needs and the ability of schools and communities to address them effectively.[13] One of the key areas of concern is the gap in access and educational outcomes for students from different backgrounds. Despite Indonesia's policy of "education for all", the reality is that the special rights and needs of individuals with special needs have not been fully accommodated, with a variety of socioeconomic and cultural factors contributing to this inequality.[14] For example, a study on science education for students with special needs in Indonesia found that many teachers rely on outdated curricula and teaching methods that do not fit the diverse learning needs of their students, leading to poor academic outcomes. Similarly, research on inclusive education more broadly has highlighted the ongoing challenges of changing societal attitudes and building the capacity of schools and communities to support the inclusion of children with special needs.[13,14]

Analytical thinking in integrated decision-making on socio-scientific problems aims to enable students to

explore materials and problems so that they have a deep understanding to be able to give rise to open and complex thinking. It is expected that students can take relevant information according to the problem and logically arrange the problem to be used as a basis for decision-making.[15] Socioscience problems cannot be solved based on simple causal reasoning, the first thing students must master is to understand and explain socioscience problems and their complexity. Furthermore, students must come up with many solutions from different perspectives, and finally be able to critically evaluate the developed solutions.[16] The learning process must consider the diversity of students. Gender issues are urgent issues that demand immediate solutions. Gender is only categorized into male or female. Research on socioscientific decision-making based on gender, in general, is not done too much.[17,18] Research [19] states that gender has an influence on anxiety in decision-making. Gender has the potential to make a major contribution to decision-making. Personal emotions and experiences are worth considering in decision-making because they vary for each individual, especially between men and women.[18] [20] found that gender differences have no effect in terms of the construction of ideas that support arguments and refutations about scientific social issues. Studies show there is no significant difference in decision-making abilities between male and female students in a socio-scientific context. Both genders face challenges in articulating decision-making strategies and weighing personal values, which indicates the need for a better educational approach.[21,22]

External factors such as regional coverage are things that need to be considered in decision-making, because the equitable distribution of education causes imbalances in decision-making.[23] This can be illustrated from schools in the Municipality (urban) area and schools in sub-districts (rural). There is a wide gap between urban and rural schools in terms of educational performance.[23] Family factors, availability of resources and technology, socioeconomic status, and teacher quality are considered potential reasons that differentiate urban and rural students.[24] Identification of several factors that affect the difference between urban and rural schools has been carried out by [25] including socioeconomic status and family background, distance between students' homes and schools, class sizes and schools, and physical conditions of schools. In addition, the availability of academic resources, teacher qualifications, teaching strategies applied in the classroom, student abilities, and support from parents and the community.

Analytical thinking in integrated decision-making on socio-scientific problems aims to enable students to explore materials and problems so that they have a deep understanding to be able to give rise to open and complex thinking. It is expected that students can take relevant information according to the problem and logically arrange the problem to be used as a basis for decision-making.[26] Socioscience problems cannot be solved based on simple causal reasoning, the first thing students must master is to understand and explain socioscience problems and their complexity. Furthermore, students must come up with many solutions from different perspectives, and finally be able to critically evaluate the developed solutions.[27] The learning process must consider the diversity of students. Gender issues are urgent issues that demand immediate solutions. Gender is only categorized into male or female. Research on socioscientific decision-making based on gender, in general, is not done too much.[17] Research [28] states that gender has an influence on anxiety in decision-making. Gender has the potential to make a major contribution to decision-making. Personal emotions and experiences are worth considering in decision-making because they vary for each individual, especially between men and women.[20] found that gender differences have no effect in terms of the construction of ideas that support arguments and refutations about scientific social issues. Studies show there is no significant difference in decision-making abilities between male and female students in a socio-scientific context. Both genders face challenges in articulating decision-making strategies and weighing personal values, which indicates the need for a better educational approach.[21]

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Some findings suggest that urban schools score higher than rural schools. [31] reported that teaching and learning activities in border areas (including rural areas) are relatively difficult, in addition to preparing students to be able to face various dynamics that change rapidly related to science and technology, teachers must also be creative in bringing students into the phenomenon of social problems, because they are familiar with the textbooks prepared by the government. [30] reported that rural and urban students obtained the same science scores. [32] confirmed the results of his research that there were differences in socioscientific decision-making, and arguments presented by high school students in urban and rural areas in Provence, France. Another finding was conveyed by [33] that the decision-making of rural students related to academics is influenced by family support, attention, and encouragement, the need for independence, and the desire to continue education. The

effectiveness of socio-scientific decision-making education can vary by region, influenced by local educational practices and the resources available for biology teaching. Some of the articles that we have analyzed in support of this study can be seen in (table 1).

Table 1. Research Gap Analysis from Several Articles

Article Title	Gap Research	Methodology Research	Limitations	Findings
Research on the Infiltration of Scientific Spirit in High School Biology Teaching Under the Background of Curriculum Ideology and Politics Bo Peng, Piaopiao Sun, Nan Sun, et.al. 10 Nov 2024	• Insufficient understanding of ideological education among teachers. • Limited methods for integrating scientific spirit into teaching.	• Questionnaire surveys and interviews with students and teachers. • Evaluation of teaching effectiveness through various methods.	• Insufficient understanding of ideological education among teachers. • Limited methods for integrating scientific spirit into teaching.	• Limited understanding of ideological education among teachers and students. • Insufficient integration of scientific spirit in biology teaching.
Exploring Students Decision-Making Ability in the Context of Socio-Scientific Issues Dita Ardwiyanti, Zuhdan Kun Prasetyo 28 Mar 2021	• Students struggle with decision-making strategy and weighing criteria. • Need for innovative decision-making-oriented learning approaches.	• Descriptive survey method • Open-ended questionnaire adapted from Eggert and Bogeholz	• Difficulty in describing decision-making strategy • Challenges in weighing criteria according to personal values	• High development in stating options among students. • Difficulties in decision-making strategy and weighing criteria.
The Relationship of Science Knowledge and Decision-Making Based on Gender on Socioscientific Issues Haryanti Putri Rizal, Galuh Yuliani, Parsaoran Siahaan, Hasri 01 Jan 2019	• Other variables affect decision making beyond science knowledge. • Gender does not influence decision making outcomes.	• Science Instruction based on socio-scientific issues implemented. • Pre-test and post-test data collection and analysis.	• Decision making influenced by factors beyond science knowledge and gender. • Only 6,978 % correlation between science understanding and decision making.	• No gender difference in decision making observed. • Science knowledge correlates weakly with decision making.
Integrating Socio-Scientific Issues to Enhance the Bioethical Decision-Making Skills of High School Students Sally B. Gutierez 30 Dec 2014.	• Lack of diverse demographic representation in research participants. • Limited exploration of long-term effects on decision-making skills.	• Debates with science fiction presentations Workshops with role-plays and interactive techniques	• Lack of established pedagogy for integrating socio-scientific issues in science education • Need for teachers to develop students' ethical issue identification skills	• Socio-scientific issues enhance bioethical decision-making skills significantly. • Improved classroom interactions and argumentation among students observed.
Socio-scientific Decision Making in the Science Classroom Siripun Siribunnam, Prasart Nuangchalerm, Natchanok Jansawang 01 Dec 2014	• No current teaching methods for socio-scientific decision making. • Future research needed for lower secondary school students.	• Interviews, class observation, open-ended questions, free writing, audio-tape recorded discussion, and role play.	• Teachers often neglect socio-scientific issues in teaching. • Students lack skills in decision making and group work.	• Socio-scientific decision making enhances scientific literacy and inquiry. • Recommended methods include interviews, observations, and role play.
Implementation of Socioscientific Issues Instruction to Fostering Students' Decision Making Based Gender on Environmental Pollution H P Rizal, P Siahaan, Galuh Yuliani 01 Feb 2017	• Influence of ethnic and cultural factors on decision making. • Impact of emotional factors on decision-making abilities.	• One group pretest-posttest design methodology used. • Instruments included essay questions and observation sheets.	• Group discussions may hinder cooperation in heterogeneous groups. • Gender stereotypes may influence decision-making perceptions.	• Instruction successfully implemented with positive student and teacher responses. • No significant decision-making difference between male and female students.
Prompting students to make socioscientific decisions: embedding metacognitive guidance in an e-learning environment Ying Shao Hsu, Shu Sheng Lin 18 Apr 2017.	• Influence of personal value judgment on decision-making not considered. • Need for further studies on metacognitive guidance mechanisms.	• Experimental design to investigate metacognitive prompts' impact. • E-learning environment and research instruments developed for assessment.	• Did not consider personal value judgment effects. • Limited exploration of metacognitive guidance mechanisms.	• Metacognitive guidance improved decision-making skills significantly. • Experimental group outperformed comparison group in specific DM skills.

Enhancing Decision-Making in STSE Education by Inducing Reflection and Self-Regulated Learning Helge Gresch, Helge Gresch, Marcus Hasselhorn, Susanne Bögeholz 01 Feb 2017.	• Influence of self-regulation on younger students' decision-making. • Effective methods for different age groups' decision-making training.	• Computer-based training program for decision-making strategies. • Reflection on decision-making processes of others.	• No effect on integrated advantages and disadvantages noted. • Influence of development on metacognitive skills not investigated.	• Training groups improved decision-making competence compared to control group. • Self-regulated learning enhanced reflection and metadecision aspects significantly.
Scientific reasoning skills based on socio-scientific issues in the biology subject Muhamad Ikhwan Mat Saad, Sadiah Baharom, Siti Eshah Mokhsein 01 Mar 2017.	• Students' low competency in SSI reasoning skills. • Inability to connect science concepts with socio-scientific issues.	• Quantitative approaches surveys • SSI instruments adapted for assessment	• Students' accomplishment in SSI reasoning is low or medium. • Incompetence in relating science concepts to socio-scientific issues.	• Student's scientific reasoning levels are low or medium. • Incompetence in relating science concepts to socio-scientific issues.
High school students' reasoning in making decisions about socio-ethical issues of genetic engineering: case of gene therapy Teodora Kolarova, Isa Hadjiali, Iliya Denev 01 Jan 2013-2016.	• Limited exploration of emotive and intuitive reasoning patterns. • Need for broader context beyond gene therapy scenarios.	• Pre-test questionnaire on gene therapy scenario. • Peer group discussions followed by post-test questionnaire.	• Emotive and intuitive reasoning patterns were less frequently used. • Study focused on a specific socio-scientific issue only.	• Students relied on rationalistic reasoning for decisions. • Group discussions changed students' decisions and reasoning patterns.

According to this information, no study has ever been done that looks at the socioscientific choices made by high school students in the discipline of biology based on gender and geographical coverage. This type of study is necessary because it can advise policymakers and educators on how to support students' socioscientific decision-making by considering geographical coverage and gender differences. Consequently, this study's goal is to determine whether method of the decision-making process concerning social and scientific problems is preferable either male or female students.

METHOD

This study aims to explore the extent to which gender and geographical location affect students' socio-scientific reasoning. To achieve the research objectives, a quantitative research approach with an ex post facto design is used.

The research population consisted of all tenth-grade students in West Kalimantan Province. The sample of this study amounted to 912 students selected from public and private high schools in Pontianak City, Teluk Keramat District, and Paloh District, West Kalimantan Province, Indonesia.

This study uses a stratified random sampling method, with stratification based on two main factors, namely school area (urban and rural) and gender (male and female). From the population, schools are selected purposively based on regional representation, then a sample of students is randomly taken from each level considering a balanced gender proportion.

Furthermore, students are categorized based on gender and regional coverage. The gender criteria are classified as male and female, while the area coverage criteria are divided into urban (city) and rural (sub-district) (table 2).

Table 2. Sample Characteristics

		N = 912	
		N	%
Gender	Man	362	39,65
	Woman	550	60,29
Area Coverage	Urban	364	39,82
	Rural	548	60,09

This research procedure involves data collection through essay assessments to evaluate students' ability to make socioscientific decisions, with data analysis techniques using statistical tests, while the reliability and validity of the instrument are determined through expert validation, empirical testing, and Pearson correlation analysis to assess the validity of the items.

This research was conducted in accordance with research ethics principles, where all participants were

provided with clear information about the research objectives, and their consent was obtained prior to data collection. The participants identities were kept confidential, and participation in the study was voluntary without coercion. All data collected will be used solely for the purpose of this research and will not be disclosed without permission.

Use essay assessments to evaluate students' ability to make socioscientific decisions. To ensure the construct validity of the essay question, the reliability of this research instrument has been established through expert validation and empirical testing. To increase the instrument's quality at this point, recommendations and professional counsel are both essential. In this study, it was also done to determine the test's reliability and validity. In contrast to test reliability, test validity is determined by Pearson correlation. An item's validity is assessed using the correlation coefficient, which is then used to decide whether the item will be employed in the study. Test results for the instrument's validity and reliability demonstrate that there are enough dependable criteria for its use (0,51).[34] The results of the instrument validity test are summarized in table 3.

Table 3. Test Results of Test Instrument Validity

Items	Pearson Correlation	Description
1	0,783	Valid
2	0,779	Valid
3	0,875	Valid
4	0,850	Valid
5	0,957	Valid
6	0,865	Valid
7	0,918	Valid
8	0,965	Valid

The essay exam is given during class time. In 60 minutes, eight essay questions were answered. The evaluation of student responses follows the criteria for socioscientific judgment. The rubric used was developed by [35]. The description of the rubric is presented in table 4.

Table 4. Socioscientific Decision Making Rubric

Indicators	Score			
	4	3	2	1
Describing the Problem	Explain more than two socioscientific and related problems	Explain two socioscientific and related problems	Explain two socioscientific but unrelated problems	No response
Developing Solutions	Develop solutions based on 2-4 aspects of problems and related	Develop solutions based on 2-4 aspects of the problem	Develop solutions based on one aspect of the problem	No response
Evaluating Solutions	Evaluate solutions based on more than one aspect of the problem	Evaluate solutions based on 2-4 aspects of the problem	Evaluate A solution that only focuses on one aspect of the problem	Evaluate solutions but are unsubstantiated
Suggest Solution Fixes	Make reasonable suggestions based on more than one related aspect	Make reasonable suggestions based on 2-3 aspects	Make sensible and grounded suggestions from one aspect	Making reasonable but unfounded suggestions

Source: [35]

To ensure the consistency of scores between assessors in assessing essays, an inter-rater reliability test was carried out using Cohen's Kappa. Two independent assessors assessed students' essays based on four indicators in the rubric, namely 1) Describing the Problem; 2) Developing Solutions; 3) Evaluating Solutions; 4) Suggest Solution Fix.

Cohen's Kappa analysis was conducted to measure agreement between ratters in each indicator.[36] The results of the analysis are shown in table 5.

Table 5. Test Results of Test Instrument Validity

Indicators	Cohen's Kappa	Interpretation
Describing the Problem	1,00	Perfect agreement
Developing Solutions	0,87	Perfect agreement
Evaluating Solutions	0,76	High agreement
Suggest Solution Fix	0,74	High agreement

These results show that the raters have very high agreement in all indicators. This indicates that there is no difference in understanding between assessors in assigning scores to all indicators, so that the assessment instrument can be considered reliable and consistent.

Socioscientific decision-making based on sex differences was measured testing the difference between the two groups with the Mann-Whitney U test at a 5 % significance level. Normality and homogeneity tests are prerequisites that must be met before hypothesis testing can be conducted. Kolmogorov Smirnov is performed for data normality testing. Levene's test is used to investigate data homogeneity. The normality test results show that both gender and area coverage variables have p-values of 0,000, which are less than the significance level of 0,05, indicating that the data is not normally distributed. The homogeneity test revealed a p-value of 0,946 for sex and 0,000 for area coverage. Based on the analysis for sex, the data can be considered homogeneous, p-value > (α = 0,05); This shows that the data comes from populations that have the same variance (homogeneous), while the analysis for area coverage, p-value < (α = 0,05); This suggests that the data comes from populations that have unequal variances (heterogeny). The analyzed data was subsequently processed using SPSS Statistics version 23.

RESULT

Statistical analysis showed that there was a significant difference in socioscientific decision-making skills between male and female students. The results of the Mann-Whitney U test showed that male students had a higher average rating (486,30) than female students (436,89), with a significance value of p = 0,005 (table 6). These results showed that the difference between the male and female groups was significant at a confidence level of 95 % (p < 0,05).

Differences in socioscientific decision-making skills between male and female students are also seen in the details of the arguments given in the essay answers. Male students' answers showed a stronger argumentation structure than female students, who tended to be more descriptive in answering questions.

Table 6. Socioscientific Decision Making Based on Sex

Ranks				Test Statistics[a]
	Code	N	Mean Rank	Asymp.Sig (2 Tailed)
Gender	Man	362	486,30	,005
	Woman	550	436,89	
Total		912		

In addition, differences in socioscientific decision-making skills were also found based on the region where students went to school. Statistical analysis showed that students in urban areas had a higher average rating (499,68) than students in rural areas (427,82), with a significance value of p = 0,000 (table 7). This shows that students who attend schools in urban areas have better socioscientific decision-making skills than students who attend schools in rural areas, with a significant difference in confidence level of 95 % (p < 0,05).

Previously, in the preliminary analysis, it was found that students in urban areas had higher socioscientific decision-making skills with a difference of 11,11 % compared to students in rural areas. The results of statistical tests through Mann-Whitney U confirm that this difference is significant.

Table 7. Socioscientific Decision Making Area Coverage

Ranks				Test Statistics[a]
	Code	N	Mean Rank	Asymp.Sig (2 Tailed)
Area Coverage	Urban	364	499,68	,000
	Rural	548	427,82	
Total		912		

These results show that geographical factors affect socioscientific decision-making skills. This difference can be due to access to learning resources, technology, and a wider range of scientific discussion experiences in urban environments than in rural areas.

DISCUSSION

Sex differences in students' socioscientific decision-making

As a branch of science, biology requires students to possess the ability to construct and evaluate scientific arguments. The development of scientific argumentation skills has been recognized as a crucial goal in science education, given that socioscientific argumentation equips students to apply scientific knowledge in real-world contexts and make informed decisions.[37] According to [38] argumentation is an interaction used to evaluate the credibility of scientific problems. Furthermore, [39] stated that it is important for students to be able to argue scientifically both orally and in writing. Argumentation can facilitate students to engage in thought processes and as an informal basis for reasoning.[40] Learning that integrates socio-scientific issues provides students with opportunities to develop critical thinking and argumentation skills from multiple perspectives. [41] Constructed argumentation, as a core component of scientific literacy, serves as a crucial foundation for science-based decision-making in social contexts.[41] Research found that the arguments used by students in decision-making on socio-scientific issues vary and are specific, based on the presence of cognitive schemas. [42] The decision-making process in socioscientific issues requires a thorough evaluation of various alternative solutions, in which argumentation plays a central role.[43] The quality of a decision is highly dependent on the strength of reasoning, the completeness of arguments, and the comprehensive consideration of each option. A good argument is characterized by a claim supported by evidence and a clear explanation of the relationship between the two.[44] Therefore, students' ability to construct strong arguments is a crucial prerequisite for supporting socioscientific decision-making.[45]

Differences in urban and rural coverage in students' socioscientific decision-making

Research shows significant socioscientific decision-making differences between urban and rural students (table 7). It found that urban students were superior to rural students in socioscientific decision-making. The results of the analysis show that students in urban areas have higher average ratings than students in rural areas.

Environmental factors and access to learning resources can be potential reasons for this difference. Students in urban areas tend to have greater access to technology, educational resources, and interactions with scientific issues through various media, which may contribute to their decision-making skills.[46,47] [48] stated that inequalities in the academic performance of urban and rural students are caused by school organizational processes related to leadership and learning. [49] reported that improving achievement has always been a top priority for school leaders and teachers in urban areas. Research findings said that high school students in urban areas are more involved in learning. Student involvement in learning will affect student attitudes in learning and can foster student confidence in studying natural sciences (biology).[50] This statement was confirmed by research findings, it was stated that there is a significant difference in self-confidence levels and positive attitudes between urban and rural students, with urban students showing higher scores. There are many reasons, both from within and from the environment, why this happens.[51]

Internal factors can be influenced by motivation and learning style in studying natural sciences (biology).[52] [53] said in other cases, internal factors can be influenced by something that keeps students away from learning, such as stress in learning. Stress in learning science can be experienced by students when they cannot find evidence and information that includes credible details, figures, and statistics which are then used to make socioscientific decisions. That situation caused them to drop out of school.

Socioscientific decision-making is a central cognitive process needed to elaborate socio-scientific issues and the processing of socio-scientific issues related to sustainable development.[54] Therefore, socioscientific decision-making in biology education refers to students' ability to analyse complex issues from multiple perspectives, always grounded in scientific evidence. Therefore, socioscientific decision-making in biology education refers to students' ability to analyze complex issues from multiple perspectives, always grounded in scientific evidence.

Demographic factors influence that.

Meanwhile, external factors can come from environmental conditions and learning conditions experienced by students. This reason is supported by and in research findings that there is a tendency for students in urban areas to have a better environment, association, and learning support facilities compared to students in rural.[55] This is confirmed by [56] who states that the decision-making process requires support from the student's individual social environment to achieve the expected goals. The importance of a supportive social environment so that students can understand and evaluate environmental issues and wisely can take actions that are consistent with environmental values.[56]

Research findings specifically highlight how teachers interpret and operationalize socio-scientific issues into teaching. Various studies have shown that teaching involving socio-scientific issues contributes to critical thinking, argumentation, socioscientific decision making, learning outcomes and moral development.[57] Other findings by some educators argue that integrating socioscientific issues into the curriculum can enhance students' readiness to confront complex societal problems, as discussions on these issues train students to think rationally and critically.[58]

Implementing socioscientific issues in biology education not only enhances students' decision-making skills but also cultivates critical and creative thinking abilities, which are essential for addressing real-world scientific and environmental challenges. When students engage in socioscientific inquiry, they are encouraged to analyses evidence, consider ethical implications, and develop well-reasoned arguments, leading to a deeper understanding of biological concepts. Research has demonstrated that integrating socioscientific discussions into learning can significantly improve students' scientific literacy, cognitive learning outcomes, and argumentation skills.[59] Furthermore, students who develop strong critical and creative thinking skills tend to perform better academically, as these skills are closely linked to their ability to process and synthesize complex information.[60] In line with this, fostering creative thinking in preservice biology teachers through innovative instructional models has been shown to enhance their ability to design meaningful learning experiences that promote student engagement and higher-order thinking.[61] Thus, incorporating socioscientific issues into science education not only empowers students to become scientifically literate citizens but also prepares future educators to facilitate more effective and interactive learning environments.

Limitations

Several limitations in this study should be noted, including the limitation in geographical coverage, which only includes certain areas in West Kalimantan, and may not reflect conditions across the entire province. Additionally, this study relies on an essay assessment instrument that may not fully capture all aspects of students' socioscientific reasoning abilities. Another limitation is the external variables that may influence students' decision-making, which cannot be fully controlled in this study.

CONCLUSIONS

This research clearly demonstrates a disparity in the ability to make socioscientific decisions between urban and rural students. Urban students consistently demonstrate a higher ability to analyse complex issues, construct strong arguments, and make informed decisions. These differences can be attributed to several factors, including the quality of education, access to resources, and a more supportive social environment in urban areas.

This research highlights the importance of education in equipping students with critical thinking and decision-making skills. To address this gap, a comprehensive effort is needed, such as improving the quality of education in rural areas, integrating socioscientific issues into the curriculum, and providing training for teachers. In this way, all students, regardless of their background, can develop the skills necessary to become active and responsible citizens.

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FINANCING

The authors did not receive financing for the development of this research.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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